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65-9440

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CONTRACT REQUIREMENTS	CONTRACT ITEM	MODEL	CONTRACT NO.	DATE
Exhibit E, Para. 5.2	Line Item 13.0	LEM	NAS 9-1100	1/14/63

TYPE II

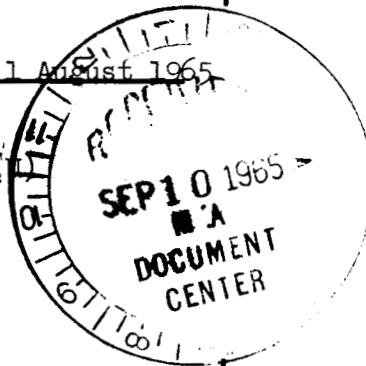
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REPORT

NO. LED-490-23

DATE: 1 August 1965

LEM MASS PROPERTY REPORT



CODE 26512

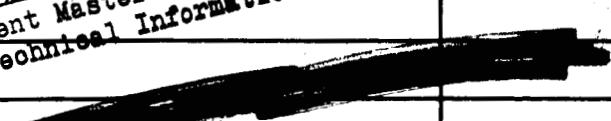
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DATE	REV. BY	REVISIONS & ADDED PAGES	REMARKS
		<p style="text-align: center;">CLASSIFICATION CHANGE</p> <p>To: UNCLASSIFIED Date: 12/31/77</p> <p>By authority of GPO 100-17652</p> <p>Changed by A. Shultz</p> <p>Classified Document Master Control Station, NAMA</p> <p>Scientific and Technical Information Facility</p> 	

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GROUP 4. DOWNGRADED AT
3 YEAR INTERVALS; DECLASSIFIED
AFTER 20 YEARS

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~~CONFIDENTIAL~~INTRODUCTION

This report contains the LEM Mass Properties Status as of July 21, 1965 for the Lunar Landed Vehicle. The total weight at Separation is 32,655 pounds, which is 1,359 pounds heavier than that previously reported in LED-490-22, dated 1 July 1965.

A summary of changes since the last report is as follows:

A. Ascent Stage inert * weight	+238#
B. Ascent Stage propellant	+154#
C. Descent Stage inert * weight	+228#
D. Descent Stage propellant	+739
Total LEM Weight Change at Separation	+1359#

A more detailed breakdown of the changes since the last report is included on page 15.

In addition this report is also intended to provide some clarification of the LEM current weight status, its problems and to propose a solution to the LEM weight growth problem. In this regard this report departs from the previous report content.

As such this report defines:

1. The Current Weight Status.
2. Current Weight Status uncertainties.
3. Current Weight Classification (estimated, layout, calculated, actual and GFE).
4. Projection of Growth Trends and prediction of Weight Growth.
5. Weight Reduction Plan.

A. Change in Reported Weight Format and Intent

Several recent discussions with ASPO has indicated that a considerable amount of confusion exists regarding the data contained in the LEM Monthly Mass Property Report and the basic intent of the contained data. There have been many misinterpretations of the report format. Reports submitted up to August included component weights which were relatively well defined. Changes which were not well defined and/or not evaluated at the time of report submittal were included in the Pending Change Section of the report but not included in the reported LEM Current Weight.

* Inert weight includes all non-propulsion expendables.

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A. Change in Reported Weight Format and Intent - Cont.

This approach had been discussed and agreed to between MSC Weight Control Branch and GAEC Mass Property Control Group.

Recent events required a different format of weight data. The format required is one which would define the LEM weight if every area was considered frozen with no opportunity to implement weight reduction or improvement ideas. Because of this different usage of LEM weight data, the following approach will be used for this and subsequent LEM Mass Property Reports:

1. Include the latest component data prior to review and evaluation. Review and evaluation to reduce the weight change will occur subsequent to reporting the data in the LEM current status. Items which can be reviewed with changes implemented prior to the next report submittal can be handled as before. Items which have not been reviewed, will be incorporated in the report with some discussion of when the review and evaluation will be completed. In each case, action items will be established only after review and evaluation.

The main impact of this change in data handling is to incorporate the items which have been previously listed as pending weight changes. As such all vendor reported weights, except one, and the present thermal/meteoroid shielding configuration have been incorporated in this report. The exception is the Hamilton Standard reported weights for the ECS. These have been reduced 20 pounds, from their last reported weight, based on a review of the ARS Support Structure and Packaging. Revision of the support structure machining and packaging provides the weight reduction to their reported weight.

The LEM current weight status is included on pages 7 thru 21, and weight classification is shown on page 10. This section also includes a comparison of Ascent Propellant requirements for a normal Lunar Launch and for the critical abort, on page 6.

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B. LEM Weight Growth - Past and Future

The LEM weight has had a history of rapid growth. This growth is shown on figure 2. Many reasons exist as to its high rate of growth (i.e. poor estimates, many changes in requirements, resizing, etc.) but the fact remains that a high rate of growth does and has existed. The 1 August status is at the Maximum Control Weight and is also at the maximum capability of the Descent propulsion system (tanks, engine, etc.). This data plus stage and subsystem growth trends appear on figures 2 through 4. On figure 2, two predictions have been made, one based on the past growth rate, and the other based on the MSC prediction of 6% growth in descent stage and 11% growth in the ascent stage. The predictions taken out to LEM 4 launch result in a LEM Separation Weight of 39,000 Lbs., based on past growth and 35,600 Lbs. based on the 6 and 11% growth rates.

In addition, a summary of weight uncertainties to the 1 August weight has been compiled by listing specific items which could increase or decrease the August weight. This listing is included on pages 27 thru 30 and these points are shown on figure 2 as minimum/maximum weights for 1 August. The minimum weight shown is 30,959 and the maximum is 35,229 pounds at Separation. The significance of these points is that:

- (1) The possible increases are higher than the possible decreases.
- (2) Past experience indicates that a higher probability of implementation exists for possible increases, than possible decreases.
- (3) The total range of weight uncertainty, associated with the minimum-maximum weights, is large.

C. Weight Reduction Plan

In view of the problem indicated by the current weight status, the predicted weight growth trends, the weight uncertainties and the inadequate effectiveness of the previous LEM weight control program, Grumman is embarking on a more stringent weight control program which has been titled - the Super Weight Improvement Program, or SWIP. This program was used effectively by Grumman, General Dynamics and the Military on the F111B aircraft program. This SWIP Program and its past effectiveness on the F111B was presented at the August 3 LEM Management Review Meeting and the material presented is included on Pages 33 thru 35.

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C. Weight Reduction Plan- Cont.

This program will require extensive effort by all the LEM management groups, including NASA, Grumman, Associate Contractors, and Grumman Subcontractors. This effort will include several facets:

1. Scrape
2. Requirements Review Program
3. Redesign and Reconfiguration

Determination of the applicability of the above facets to individual components can only be determined by a thorough review of the items, and their degree of development.

Scrape consists of the review of detail drawings to literally reduce the parts to a minimum weight design. In some cases it also includes minor reconfiguration and redesign, but this effort is limited to Grumman responsibility changes which do not violate the LEM Specification. Grumman has already embarked on this phase of the SWIP Program. The personnel listed on Table 7 have been devoting the majority of their time reviewing LEM drawings with the aid of the cognizant subsystem engineers. This effort has included subcontractor equipment crew furnishings and structure. Some examples of items either in review or which have been reviewed are listed on Pages 36 through 39.

Requirements review will require a thorough evaluation of all critical design requirements at all levels. These levels will include both Grumman generated requirements and NASA imposed requirements. The purpose of this review will be to determine which requirements can be reduced, and the associated weight savings. All proposed changes to NASA imposed requirements will be submitted for NASA evaluation. Those changes which are approved will then be implemented after receipt of an engineering change proposal.

Redesign and reconfiguration will be handled in the same manner as requirements changes.

D. Conclusion

The weight problem has not improved despite our best efforts since November 1964. Further action is required NOW!!

The weight reduction plan (SWIP) outlined above was effective before and it can be effective for the LEM if MSC and GAEC both wholeheartedly support it.

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COMPARISON OF LEM PROPELLANT REQUIREMENTS FOR ASCENT
FROM THE LUNAR SURFACE AND FOR ABORT FROM NEAR TOUCHDOWN

The ΔV budget for ascent from the lunar surface is 6586 ft/sec. From reference 10, the required ΔV for abort when the LEM is near touchdown is 6400 ft/sec. Parking orbit techniques are required. It is assumed that the PNGCS is used and that there is no assistance from the descent engine. The ΔV figure of 6400 ft/sec applies only to aborts with fully operational ascent propulsion and RCS. Other assumptions are stated in reference 10. Following is a comparison of the abort ΔV breakdown (reference 10) with the ΔV budget (reference 6).

<u>MISSION PHASE</u>	<u>ABORT ΔV(ft/sec)</u>	<u>BUDGET ΔV(ft/sec)</u>
Boost to 50,000 ft.	6041	6001
Transfer/& Plane Change	159	149
Midcourse Corrections	75	75
Rendezvous	100	336
Docking	25	25
 Totals	 6400	 6586

The determination of whether ascent from the surface or abort is critical for propellant requirements depends upon the difference between the weights of the LEM ascent stage in the two cases. Since the ΔV for abort is less, this case is not critical except for ascent stage weights in excess of some amount more than the lunar launch weight. This amount is about 200 pounds. For example, if the ascent stage weight near touchdown was 10,750 pounds and the expected lunar weight was 10,500 pounds (based on 250 pounds of inert weight jettisoned on the surface) the abort case would require more propellant. But if the former weight were 10,650 pounds with an expected lunar launch weight of 10,500 pounds, the ascent from the surface would require more propellant. Currently, the jettisoned weight is less than 200 pounds, so the lunar launch case is critical.

LEM ALLOWABLE STAGE WEIGHT ALLOCATION

VEHICLE

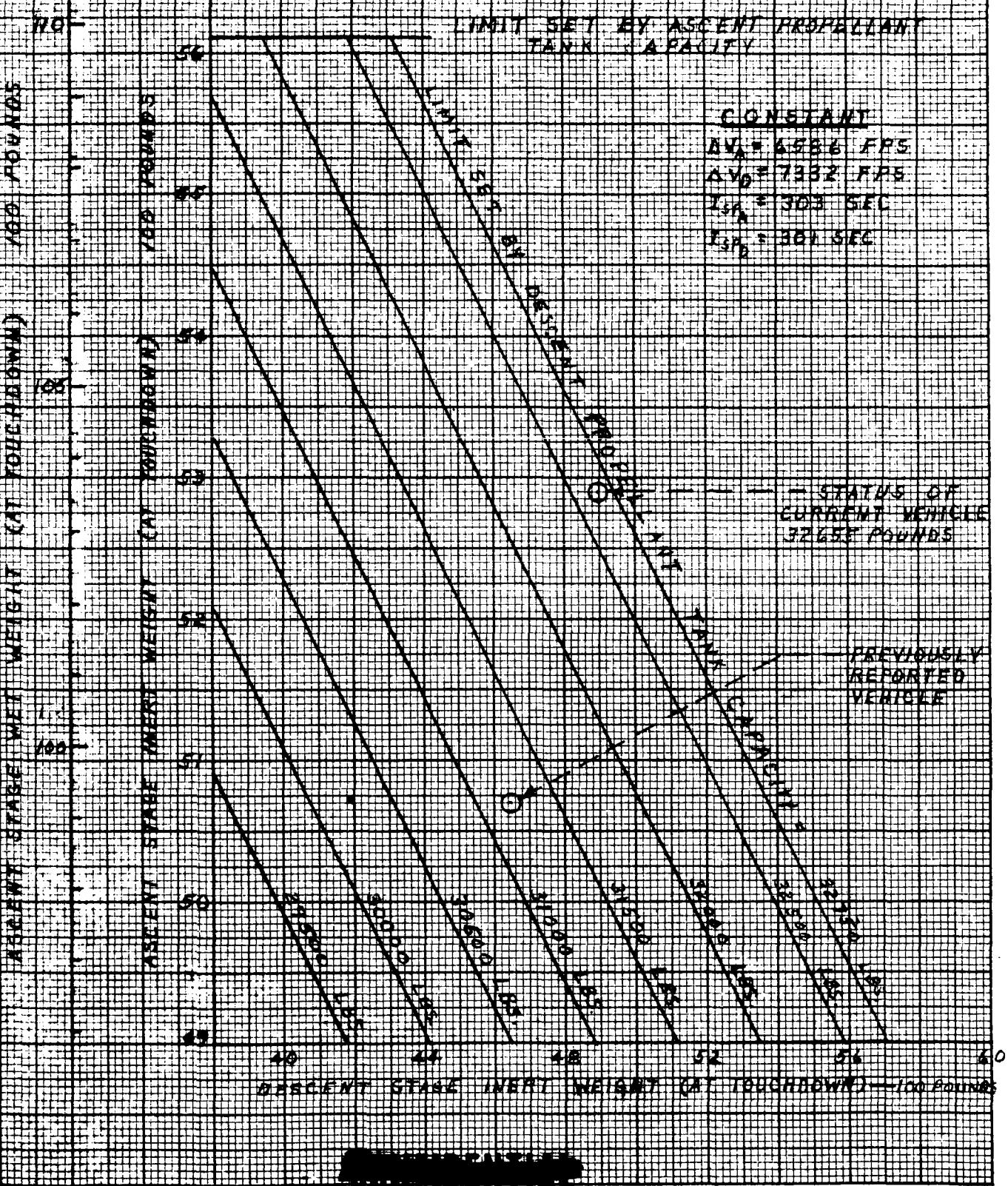


Table 1LEM MASS PROPERTY HISTORY - CURRENT WEIGHT

MISSION PHASE	WEIGHT EARTH POUNDS	CENTER OF GRAVITY			MOMENTS OF INERTIA			PRODUCTS OF INERTIA					
		STATION INCHES	STATION INCHES	DISTANCE FROM THRUST AXIS	X	Y	Z	I _{xx}	I _{yy}	I _{zz}	I _{yz}	I _{xz}	I _{xy}
Translunar Injection	32057	183.6	0.5	-1.1	21645	23728	24204	266	-157	-221			
LEM/CSM Separation	32655	185.0	1.1	0.1	23516	25484	25498	461	423	144			
End Insertion To Hohman -Descent	32202	184.8	1.2	0.1	23221	25204	25245	452	412	134			
Begin Hover	17087	204.3	2.1	0.3	13237	15890	18091	473	371	1			
Lunar Touchdown	15202	212.6	2.3	0.4	12052	13010	15470	473	360	-62			
Lunar Launch (Lift-off)	10202	242.6	0.6	1.1	6380	3276	5532	18	122	76			
End Insertion To Hohman -Ascent	5424	254.4	1.2	2.2	3038	2760	1811	24	93	52			
Burnout (Docked)	5128	255.0	1.3	2.3	2875	2674	1579	28	91	51			
Completion of Crew Transfer	4514	255.3	1.1	-2.9	2546	2360	1446	36	127	43			

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Table 2
SUMMARY OF LEM WEIGHT REPORTING MISSION

MISSION PHASE	ELAPSED TIME FROM EARTH LAUNCH		REPORTING MISSION (Day Landing) For Loading Expendables		Pre-Separation Period	Dormant Period
Description	Hours	Minutes	Hours	Minutes		
Prelaunch (Launch Vehicle Fueling)	-10	0	10			
Launch	0	0			12	
Earth Parking Orbit		12	2	49		
Translunar Injection	3	1			5	
Translunar Coast- Prior to Transposition	3	6			15	
-During Transposition	3	21			30	
-Subsequent to Transposition	3	51	60	24		
Lunar Orbit- Insertion	64	15			6	
-Coast Prior to Separation	64	21	1	26		
-Checkout	65	47	2	17		
	68	4				
LEM Separation and Insertion to Descent Transfer Orbit					20	
Coast in Descent Transfer Orbit	68	24			58	
Powered Descent (& Hover)	69	22			10	
Lunar Staytime	69	32				
	104	17	34	45		
Powered Ascent					7	
Parking Orbit Contingency ***	104	24			47	
Coasting Ascent Transfer					8	
Rendezvous	105	11			15	
Docking	105	19			10	
Crew Transfer	105	34				
	105	44				
Dormant LEM Time			75	47		
Active LEM Time			39	57		
Post-Separation LEM Time			(37)	(40)		
Total LEM Period			115	44		

* Descent Period - 1 Hour 28 Minutes

**Ascent Period - 1 Hour 27 Minutes

***The Design Reference Mission (DRM) does not appear to have any Parking Orbit Contg..

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Table 3

LEM WEIGHT BY STAGES AT EARTH LAUNCH AND LUNAR ORBIT SEPARATION
AND DISTRIBUTION OF THE INERT WEIGHT IN PERCENTAGE

		WEIGHT	ASCENT	DESCENT	TOTAL	ESTIMATE	LAYOUT	PERCENTAGE CALCULATION	ACTUAL	GFE
1.0	Structure	(1326.4)	(1499.2)	(2825.6)	46.7	16.7	35.2	1.4	--	--
	-Ascent	1326.4	--	1326.4	26.3	26.0	46.7	3.0	--	--
	-Descent	--	1499.2	1499.2	64.7	10.2	25.1	--	--	--
2.0	Stabilization and Control	86.5	15.4	101.9	100.0	--	--	--	--	--
3.0	Navigation and Guidance	288.5	37.3	325.8	32.5	--	--	--	--	67.5
4.0	Crew Provisions *	189.6	20.0	209.6	36.0	--	--	--	--	64.0
5.0	Environmental Control	(386.5)	(344.0)	(730.5)	42.6	6.8	50.6	--	--	--
	-Hardware	249.7	89.5	339.2	6.0	15.9	78.1	--	--	--
	-Expendables **	136.8	254.5	391.3	67.8	--	36.2	--	--	--
6.0	Landing Gear	--	531.1	531.1	17.6	28.9	48.9	4.6	--	--
7.0	Instrumentation	201.8	175.0	376.8	25.9	29.0	--	--	45.1	--
8.0	Electrical Power Supply	767.1	656.4	1123.5	42.9	--	57.4	--	--	.5
9.0	Propulsion	(695.4)	(1640.1)	(2335.5)	34.2	7.2	58.6	--	--	--
	-Ascent Hardware	556.0	--	556.0	22.1	2.8	75.1	--	--	--
	-Descent Hardware	--	1135.0	1135.0	12.2	5.6	82.2	--	--	--
	-Helium	13.0	50.0	63.0	100.0	--	--	--	--	--
10.0	Propellant-Trapped	129.4	455.1	581.5	81.4	15.4	3.2	--	--	--
	-Hardware	(546.8)	--	(546.8)	73.3	22.7	4.0	--	--	--
	-Helium	303.0	--	303.0	51.9	41.0	7.1	--	--	--
	-Propellant-Trapped, Attitude and Contingency	2.1	--	2.1	100.0	--	--	--	--	--
11.0	Communications	103.5	15.6	119.1	100.0	--	--	--	--	--
12.0	Controls and Displays	213.1	--	213.1	90.6	--	--	--	--	9.4
		--	--	--	--	--	--	--	--	--
	Inert-Sub-Total - Hardware									
	- Expendables and GFE									
	Inert Totals									
	△V Propellant									
	-Main Propulsion	4895.2	4934.1	9739.3	13.0	9.8	40.6	1.0	5.6	
	-Reaction Control	(5037.5)	(4780.5)	(22318.0)						
	Totals-Earth Launch	4739.8	4780.5	22020.3						
		297.7	--	297.7						
		9812.7	22214.6	32057.3						
4.0	Crew Provisions	526.5	--	526.5	10.9	48.2	1.2	--	29.8	
5.0	Environmental Control	-1.0	-12.3	-13.3						
7.0	Instrumentation	80.0	--	80.0						
10.0	Reaction Control - Attitude Propellant	-4.4	--	-4.4						
11.0	Communications	8.8	--	8.8						
	Totals - Separation	10452.6	22202.3	32654.9						

* Without crew, suits, PLSS, radiation dosimeters, etc. (526.5 pounds).

** Includes trapped, LiOH cartridges, oxygen, coolant and water.

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Table 4

LEM CURRENT WEIGHT MISSION HISTORY BY STAGES

MISSION PHASE AND CONSUMABLE DESCRIPTION	ASCENT STAGE	DESCENT STAGE	TOTAL WEIGHT (LBS)
	DRY WEIGHT (LBS)	ΔV-PROPELL. WEIGHT (LBS)	
EARTH LAUNCH AND TRANSLUNAR INJECTION	4805.2	5037.5	4934.1 17280.5 32057.3
Crew and Equipment RCS - Checkout Propellant ECS - Umbilical Hardware - Oxygen - SOX - Water Scientific Equipment Comm - TV Camera	+526.5 -4.4 -1.0 +80.0 +8.8		-1.5 -10.8
SEPARATION	5415.1	5037.5	4921.8 17280.5 32654.9
Water and Oxygen Descent ΔV Propellant - Main - RCS RCS-Attitude		-16.1	-29.7 -17280.5
LUNAR TOUCHDOWN	5288.9	5021.4	4892.1 15202.4
Scientific Samples & Equip. Jettisoned on Lurain RCS - Checkout Propellant	-104.1 -4.4		-170.0 -4722.1
LUNAR LIFT-OFF	5180.4	5021.4	10201.8
ECS - GOX - Water Ascent ΔV Propellant - Main - RCS RCS-Attitude Propellant	-.8 -25.0 -26.1	-4739.8 -281.6	
BURNOUT (DOCKING)	5128.5		5128.5

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		LEM						WEIGHT STATEMENT			
CODE	ITEM	7/1/65 WEIGHT AT SEPARATION	BURN OUT	CONS'D ON ASCENT	JETT. ON LURAIN	CONS'D ON DESCENT	CURRENT WEIGHT	TOTAL SEPARATION	X-LUNAR EARTH EXPEND- ABLES	LAUNCH TOTAL	
1.0	Structure	2555.0	1326.4		1499.2		2825.6			2825.6	
2.0	Stabilization and Control	89.0	86.5		15.4		101.9			101.9	
3.0	Navigation and Guidance	318.0	288.5		37.3		325.8			325.8	
4.0	Crew Provisions	(736.1)		(107.0)		(736.1)	(-526.5)	(209.6)			
	-Inert	698.1		69.0		698.1	-526.5	171.6			
	-Expendables	38.0	0	38.0		38.0	38.0	38.0			
5.0	Environmental Control	(668.0)	(347.1)	(25.8)	(314.6)	(29.7)	(717.2)	(13.3)	(730.5)		
	-Inert	335.1	293.3	0	91.0	0	384.3		384.3		
	-Expendables	332.9	53.8	25.8	223.6	29.7	332.9	13.3	346.2		
6.0	Landing Gear	560.0			531.1		531.1			531.1	
7.0	Instrumentation	444.4	281.8		175.0		456.8	-80.0		376.8	
8.0	Electrical Power	1397.4	767.1		656.4		1423.5			1423.5	
9.0	Propulsion	(23366.4)	(695.4)	(4739.8)	(1640.1)	(17280.5)	(24355.8)		(24355.8)		
	-Inert	2247.2	695.4	0	1640.1	0	2335.5		2335.5		
	-Expendables - Δ V Propellant	21119.2	0	4739.8	0	17280.5	22020.3		22020.3		
10.0	Reaction Control	(855.1)	(385.7)	(307.7)	(4.4)	(142.3)	(840.1)	(4.4)	(844.5)		
	-Inert	350.7	343.9	0	0	0	343.9		343.9		
	-Expendables - Att. Prop.	198.5	41.8	26.1	4.4	126.2	198.5	4.4	202.9		
	- Δ V Propellant	305.9	281.6			16.1	297.7		297.7		

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Table 5

LEM WEIGHT COMPARISON
AT SEPARATION BY STAGES

<u>Subsystem</u>	<u>Item</u>	<u>7/1/65 Weight</u>	<u>Current Weight</u>	<u>Weight</u>
A.	Ascent Stage Weight at Separation	<u>10061.1</u>	<u>10452.6</u>	<u>+391.5</u>
1.0	Structure	1212.5	1326.4	+113.9
2.0	Stabilization and Control	74.8	86.5	+11.7
3.0	Navigation and Guidance	282.0	288.5	+6.5
4.0	Crew Provisions	716.1	716.1	0
5.0	Environmental Control	336.3	385.5	+49.2
6.0	Landing Gear	--	--	--
7.0	Instrumentation - Operational	189.4	201.8	+12.4
	- Scientific	80.0	80.0	0
8.0	Electrical Power Supply	737.6	767.1	+29.5
9.0	Propulsion System	(5264.3)	(5435.2)	(+170.9)
	Propulsion Inert	559.9	569.0	+9.1
	Propellant (Includes 126.4# trapped)	4704.4	4866.2	+161.8
10.0	Reaction Control	(855.1)	(840.1)	(-15.0)
	Propulsion Inert	311.9	305.1	-6.8
	Propellant (Includes 38.8# trapped)	543.2	535.0	-8.2
11.0	Communications	105.6	112.3	+6.7
12.0	Controls and Displays	207.4	213.1	+5.7
B.	Descent Stage Weight at Separation	<u>21235.4</u>	<u>22202.3</u>	<u>+966.9</u>
1.0	Structure	1322.5	1499.2	+176.7
2.0	Stabilization and Control	14.2	15.4	+1.2
3.0	Navigation and Guidance	36.0	37.3	+1.3
4.0	Crew Provisions	20.0	20.0	0
5.0	Environmental Control	331.7	331.7	0
6.0	Landing Gear	560.0	531.1	-28.9
7.0	Instrumentation - Operational	5.0	5.0	0
	- Scientific	170.0	170.0	0
8.0	Electrical Power Supply	659.8	656.4	-3.4
9.0	Propulsion System	(18102.1)	(18920.6)	(+818.5)
	Propulsion Inert	1105.8	1185.0	+79.2
	Propellant (Includes 455.1# trapped)	16996.3	17735.6	+739.3
11.0	Communications (Portable)	14.1	15.6	+1.5
	Total Separation Weight (A & B)	<u>31296.5</u>	<u>32654.9</u>	<u>+1358.4</u>

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DISCUSSION OF WEIGHT CHANGES BY RESPONSIBILITY
AND STAGES SINCE LAST REPORT - AT SEPARATION

	<u>Inert * Wt. Chgs.</u>	<u>Effective Weight</u>		
		<u>By Stage</u>	<u>By Responsibility</u>	
	<u>Ascent</u>	<u>Descent</u>	<u>GAE/C</u>	<u>NASA</u>
Incorporation Of Applicable LTA-3 Landing Gear	(-40.4)	(-86.2)		
Review of the LTA-3 Landing Gear layout drawings and inclusion of weight reductions has resulted in a revised weight. Major gear items, i.e. primary strut, secondary struts, etc. are based on layouts and drawings. Mechanisms, splices and fasteners are based on sketches.	-40.4	-86.2		
6.0 Landing Gear	(+80.0)	(+170.6)		
CCA #111 Propulsion Weight Changes				
Among the changes, incorporated into the Contract Technical Specification and into the Master End-Item Specification and directed by CCA #111 for implementation, are continuous propellant quantity gaging of the descent propellant tanks and the imposition of new requirements on the descent engine. The propulsion portion of the propellant quantity gaging is estimated to weigh 30 pounds. Other gaging weight effects in Electrical Power, Controls and Displays, etc. will be given in subsequent reports. The LEMDE Vendor is quoting a 50 pound increase to meet the new requirements, which include a new duty cycle and an increase in chamber length for increase performance.				
Other CCA #111 changes effecting weight will be reported as soon as the information is available.				
9.0 Propulsion	+30.0			
-Propellant Quantity Gaging	+64.0			
-Descent Engine	+50.0	+106.6		

*Inert weight excludes ΔV propellant.

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DISCUSSION OF WEIGHT CHANGES BY RESPONSIBILITY
AND STAGES SINCE LAST REPORT - AT SEPARATION - Cont.

Inert *	Wt. Chgs.	Effective Weight
By Stage		By Responsibility
Ascent	Descent	GAEc NASA
(+103.0)	(+187.0)	(+831.4)

Thermal Protection Changes

The thermal shields have been listed under pending changes for several months as potential problem areas and a recent evaluation has verified the thermal protection weight increase, for the present thermal shield configuration.

Drawings have been completed for the TM-2 ascent stage. The thermal protection for TM-2 totals 298 pounds. A review of this configuration indicates that the TM-2 design could, with some effort be reduced for later LEM's to 238 pounds. This value (238 lbs.) is the best estimate for the TM-2 configuration modified for a flight LEM, which is 79 pounds over that previously reported. In addition the change from fuel cells to batteries requires a 4 mil coating which results in a 24 pound increase. This results in an increase of 103 pounds to that previously reported.

A review of the descent stage thermal protection including the Descent Engine Base Heat Shield has also been completed. Several Base Heat Shield configurations have been investigated. These configurations varied considerably in selection of types of material (Ni., Ti., etc.) and types of construction (honeycomb, stiffened sheet, etc.). Of all the designs reviewed a nickel foil, refrasil, H-film composite appeared to offer a minimum weight design. This design has been estimated at 261.6 pounds, which represents an increase of 127.1 pounds over the previously reported Base Heat Shield weight. The similar review of the remaining descent stage thermal shielding indicates a weight of 265.9 pounds, which represents an increase of 59.9 pounds over the previous report.

*Inert weight excludes AV propellant.

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DISCUSSION OF WEIGHT CHANGES BY RESPONSIBILITY
AND STAGES SINCE LAST REPORT - AT SEPARATION - Cont.

	<u>Inert * Wt. Chgs.</u>	<u>Effective Weight</u>
	<u>By Stage</u>	<u>By Responsibility</u>
	<u>Ascent</u>	<u>Descent</u>
1.0 Thermal Protection Changes - Cont.		
The 24 pounds of descent stage thermal coating, previously reported, is included in the descent stage thermal shielding weight.		
1.0 Structure	+103.0	+432.6
-Ascent Stage Thermal Shielding		+271.1
-Descent Stage Base Heat Shield	+59.9	+127.7
-Descent Stage Thermal Shielding		
1.0 Electrical Explosive Device Change	(+4.0)	(+10.8) (+39.8)
A review of the current Electrical Explosive Device configuration indicate considerable weight change associated with the configuration freeze and component selection. Weight estimates, derived from actual vendor weights of similar equipment, increase the weights of the Deadface Interrupter (10.4#) and the Interstage Cutter (8.0#). The addition of a relay box and the increase of relays from 4 to 22 increases the relay boxes' weight 7 pounds. Additional connectors, required by the increase in relays, also tend to increase the wire weight.		
1.0 Structure	+ 1.4	+ 5.9
-Deadface Interrupter		+ 2.6
-Interstage Cutter		
8.0 Electrical Power Supply	+ 7.0	+14.9
-Relay Boxes (2)	+ 2.6	+16.4
-Wiring		

*Inert weight excludes ΔV propellant.

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

REPORT LED-49C-23
DATE 1 August 1965

DISCUSSION OF WEIGHT CHANGES BY RESPONSIBILITY
AND STAGES SINCE LAST REPORT - AT SEPARATION - Cont.

	Inert * Wt.	Wt. Chgs.	Effective Weight
By Stage			BY RESPONSIBILITY
Ascent			GAECA NASA

(-126.1)

Government Furnished Equipment Change

In accordance with NASA directive, ref. 7, one of the PLSS units (61 pounds) which was previously stored in the Command Module is now to be stored aboard the LEM at Earth Launch and one PLSS unit is to be left on the lunar surface. The TV camera and tripod (8.8 pounds) are transferred to the LEM just prior to Separation. The structure weight change for implementation of CCA #113 will appear in a subsequent report. This change will require an adjustment of LEM/CSM Control Weights.

4.0 Crew Provisions - PLSS Unit	--	--	-126.1
1.0 Communications - TV Camera and Tripod	--	--	-126.1

Incorporation of Current Vendor Reported Weights

A preliminary review of vendor equipments and the impact of changes imposed by NASA and/or GAECA indicates that considerable weight growth is occurring in this area. This area has been in review for several months but the results are still incomplete. The purpose of the equipment review is to make recommendations to reduce the equipment weight after the equipments designs are reviewed and the weights verified. Until this review is completed the vendors reported weights will be included as an interim means of reporting current Vendor weight status. The following is a list of equipments which are currently reported as increases:

2.0 Stabilization and Control	+ 1.2	+2.6
- Descent Engine Control Assembly	+ 1.7	+1.7
- Abort Sensor Assembly	+ .4	+47.4
- Abort Electronic Assembly	+ 1.3	

*Inert weight excludes ΔV propellant.

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

REPORT
DATE

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DISCUSSION OF WEIGHT CHANGES BY RESPONSIBILITY
AND STAGES SINCE LAST REPORT - AT SEPARATION - Cont.

	<u>Inert * Wt. Chgs.</u>	
	<u>By Stage</u>	<u>By Responsibility</u>
	<u>Ascent</u>	<u>Descent</u>
3.0 Navigation and Guidance	+6.5	+1.3
-Rendezvous Radar		+27.3
-Landing Radar		+ 2.8
5.0 Environmental Control		
-Atmosphere Revitalization - Components	+11.3	+47.4
-Packaging	+39.2	+164.5
-Heat Transport Components	+ .8	+ 3.4
-Oxygen Supply and Cabin Pressure Components	-2.2	-9.2
-Water Management Components	+2.3	+9.7
7.0 Instrumentation		
-Signal Conditioner	-4.0	-16.8
-Pulse Code Modulation and Timing Equipment	+6.4	+26.9
-Caution and Warning Electronics Assembly	+10.0	+42.0
8.0 Electrical Power Supply		
-Inverters	+6.0	+25.2
-Relay Junction Box	+ .7	+2.9
-Deadface Relay	-3.5	-14.7
-Electrical Control Assemblies	-9.4	-67.2
9.0 Propulsion		
-Ascent Engine	+ 9.1	+38.2
-Pressure Regulator	- .8	- 1.7
10.0 Reaction Control		
-Propellant Quantity Gaging System	+ .7	+ 2.9
-Helium Tanks	+ .6	+ 2.5
-Thrust Chamber Assemblies	-8.1	-34.0

*Inert weight excludes ΔV propellant.

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DISCUSSION OF WEIGHT CHANGES BY RESPONSIBILITY
AND STAGES SINCE LAST REPORT - AT SEPARATION - Cont.

		<u>Inert * Wt. Chgs.</u>	Effective Weight	
			By Responsibility	
			<u>By Stage</u>	<u>GAEC</u>
		<u>Ascent</u>	<u>Descent</u>	<u>NASA</u>
11.0	Communications	+1.0	+4.2	
	-VHF- Transceiver	+ .1	+ .4	
	-Signal Processor Assembly	+2.3	+9.7	
	-S-Band-Transceiver	+1.8	+7.6	
	-Power Amplifier	+1.5	+3.2	
	-Erectable Antenna	+1.5	+6.3	
12.0	Controls and Displays	- .9	-3.8	
	-Flight Control Indicators	+6.6	+27.7	
	-Descent Entry Display Assembly	(+7.3)	(0)	(+30.7)
	<u>Miscellaneous Structure Change</u>	Implementation of weights obtained from LTA-3 detailed drawings and actual weighings in lieu of weights obtained from layouts and/or detail drawings reflect the major increase in structure weight. Coding of the ladder mounted on forward strut was transferred from Structure to Landing Gear code to consolidate the retraction of this item with the landing gear. Coding of the plumbing connectors designed into the structural cold plate was transferred from Environmental Control to Structure.		
1.0	Structure	+7.3	-11.5	+30.7
	-Miscellaneous Changes			-24.5
	-Ladder removal			+ 9.2
	-Cold Plate connectors added			

*Inert weight excludes ΔV propellant.

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**DISCUSSION OF WEIGHT CHANGES BY RESPONSIBILITY
AND STAGES SINCE LAST REPORT - AT SEPARATION - Cont.**

				<u>Inert * Wt. Chgs.</u>		<u>Effective Weight By Responsibility</u>
				<u>By Stage</u>	<u>Ascent</u> <u>Descent</u>	
				<u>GAEC</u>	<u>NASA</u>	
<u>Miscellaneous Structure Change</u>	- Cont.					
5.0	Environmental Control	- Cold Plate connectors removal		-2.2		-9.2
6.0	Landing Gear	- Ladder added			+11.5	+24.5
			(+ 33.1)			(+139.1)
<u>Miscellaneous Electrical Power Changes</u>						
		Based on current specification requirements and Level III schematics, the weight data for electrical power equipment are revised. The weights of a fuse box (.8#) and a relay box (5.0#) previously omitted are incorporated at this time. An auxiliary switch relay box (6.8#) is required for the current switching configuration since multi-pole switches are not available. A lighting control unit (16.0#) is added to regulate control panel lighting. To eliminate single point grounding of LEM equipment, powered by CSM during the Translunar period, two additional buses (6.0#) are required. The inverter control unit (1.5#) is eliminated since switches for this function are included in Controls and Displays.				
8.0	Electrical Power Supply					
		-Fuse Box	+•.8	+3.4		
		-Relay Box	+5.0	+21.0		
		-Auxiliary switch relay box	+6.8	+28.6		
		-Lighting control unit	+16.0	+67.2		
		-Buses (2)	+ 6.0	+25.2		
		-Inverter control unit	- 1.5	-6.3		
					<u><u>+227.6</u></u>	
		Total Inert Weight Changes			<u><u>+237.9</u></u>	
		Total Effective Weight Changes By Responsibility			<u><u>+1313.9</u></u>	
		Total Reported Weight Changes = +1358.4			<u><u>+144.5</u></u>	

*Inert weight excludes ΔV propellant.

GOVERNMENT FURNISHED EQUIPMENT

The only changes in Government Furnished Equipment since the previous report, ref. 8, involves the staging of equipment.

At MSC direction, see ref. 7, one of the PLSS units is stowed on the LEM at Earth Launch. Also a PLSS unit is considered jettisoned onto the lunar surface prior to lunar launch.

The camera and tripod is not considered aboard the LEM at Earth Launch but is transferred from the CSM to the LEM prior to Separation.

Another Government Furnished Equipment list will be published in the LEM Mass Property Report when a complete enumeration of Government Furnished Equipment including staging data is officially received from MSC.

K#E

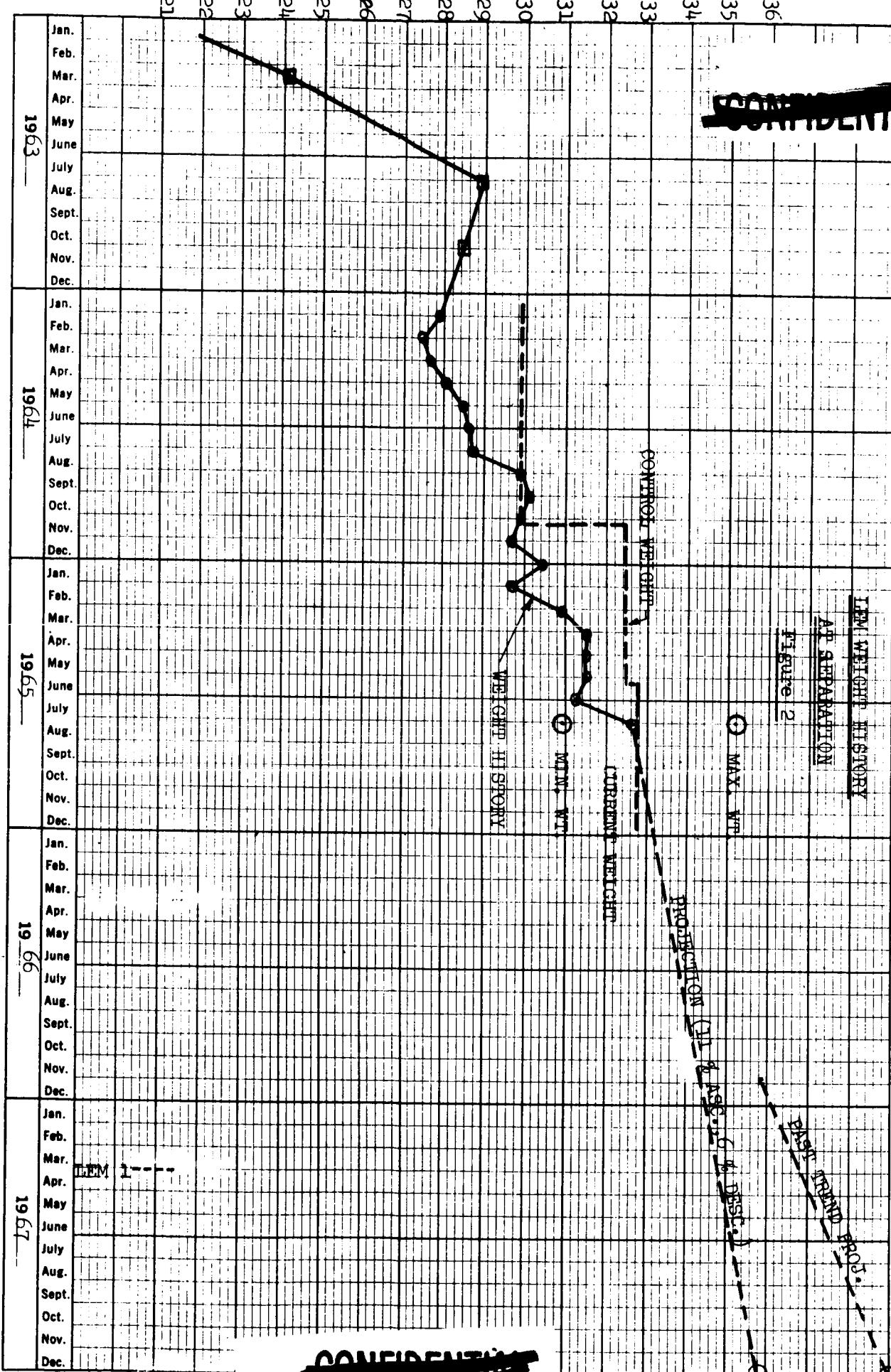
5 YEARS BY MONTHS 359-192
X 100 DIVISIONS

KUFFEL & FISHER CO.

MADE IN U.S.A.

Date 1 August 1965
Report ID-490-23

WEIGHT - THOUSANDS OF POUNDS



NOTE: = Points at which full V Budget was not attainable.

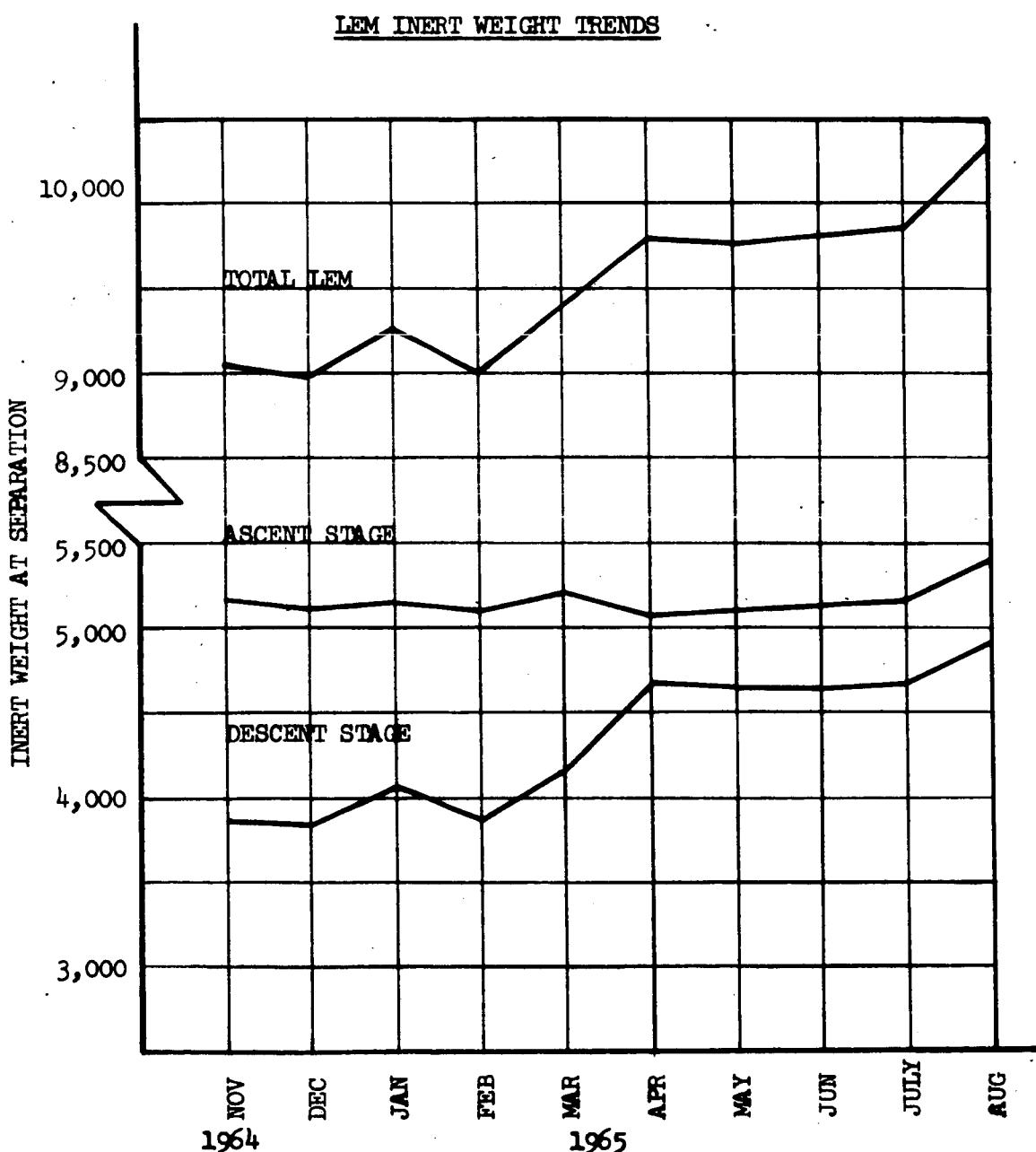
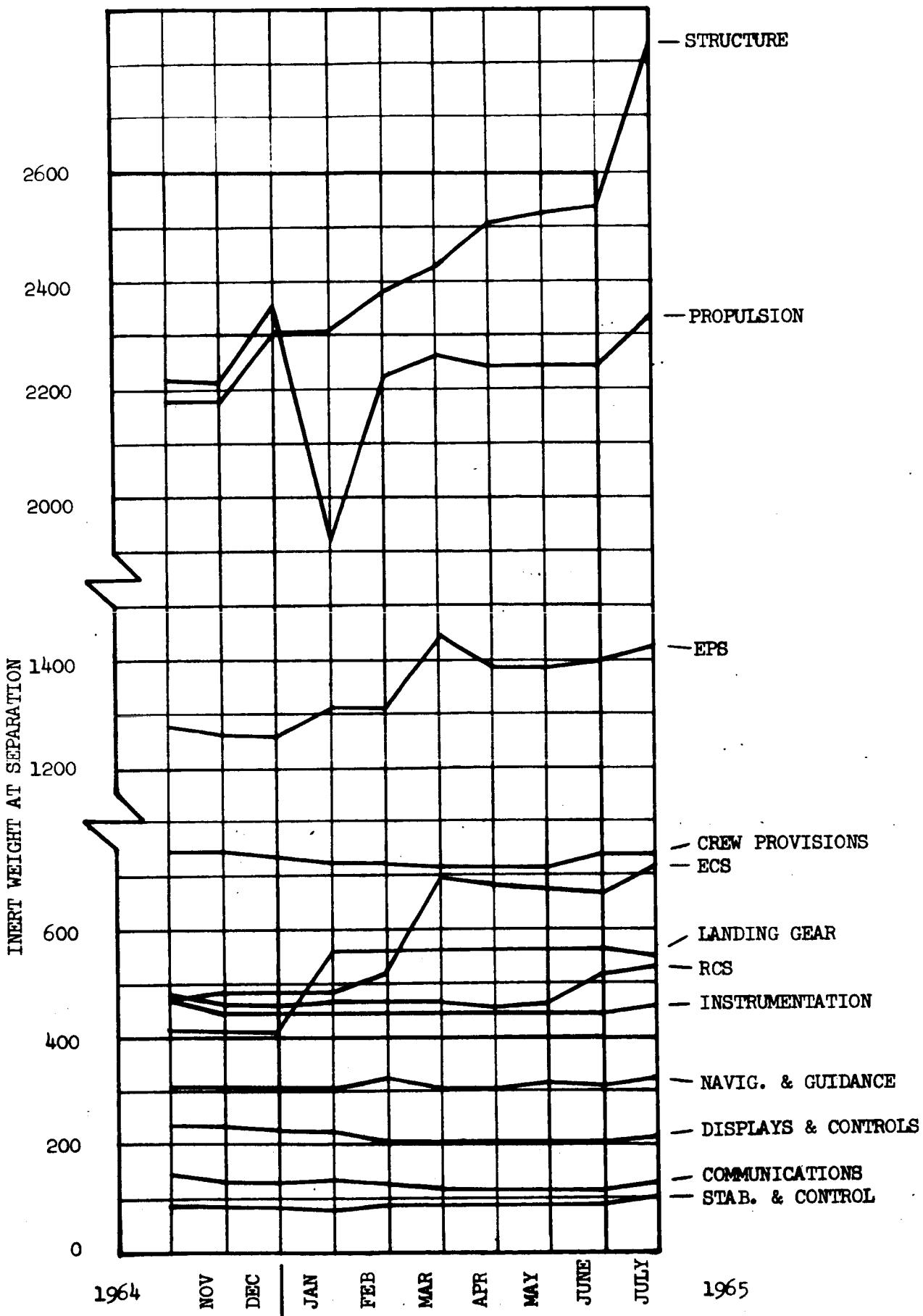
~~CONFIDENTIAL~~Figure 3

Figure 4
SUBSYSTEM INERT WEIGHT TRENDS

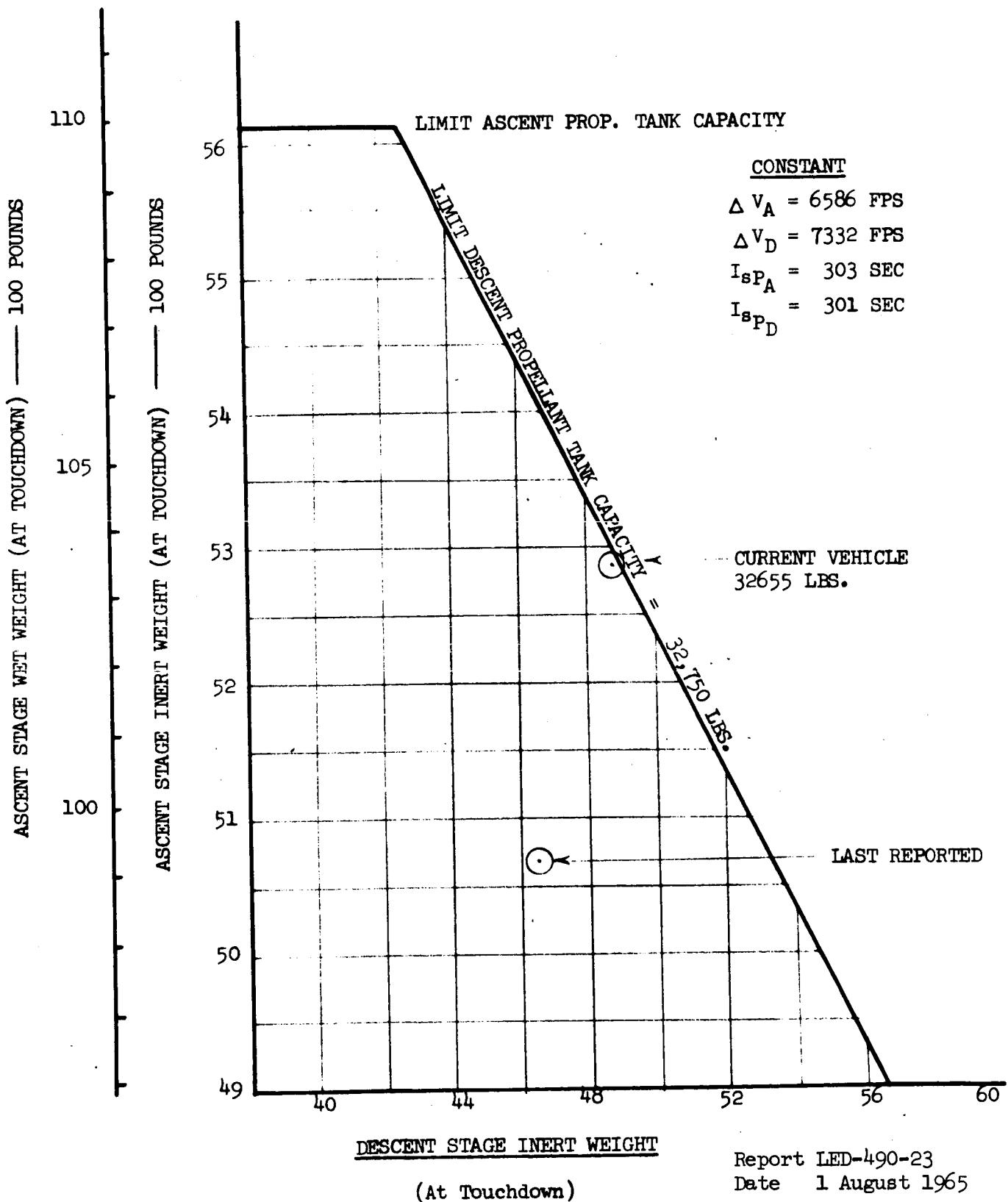
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Figure 5

LEM ALLOWABLE STAGE WEIGHT APPORTIONMENT

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Table 6
LEM WEIGHT UNCERTAINTIES
BY SUBSYSTEM AT SEPARATION

<u>SUBSYSTEM</u>	<u>MIN.</u>	<u>CURRENT</u>	<u>MAXIMUM</u>
Ascent Stage			
Structure	1246	1326	1501
Stabilization & Control	81	87	94
Navigation & Guidance	229	289	295
Crew Provision	709	716	772
ECS	375	385	412
Instrumentation	282	282	282
Electrical Power Supply	734	767	807
Propulsion	658	695	730
RCS	494	542	542
Communications	112	112	112
Controls & Displays	213	213	213
Inert Stage Total:	<u>5133</u>	<u>5414</u>	<u>5760</u>
Propellant Total - Main	4500	4740	5070
- RCS	295	298	303
STAGE TOTAL:	<u>9928</u>	<u>10452</u>	<u>11133</u>
Descent Stage			
Structure	1389	1499	1614
Stabilization & Control	15	15	15
Navigation & Guidance	37	37	37
Crew Provision	20	20	20
ECS	333	333	333
Landing Gear	421	531	531
Instrumentation	175	175	175
EPS	657	657	662
Propulsion	1589	1640	2046
Communication	16	16	16
Inert Stage Total - EL	4652	4923	5449
Propellant - Useable	16379	17280	18647
STAGE TOTAL:	<u>21031</u>	<u>22203</u>	<u>24096</u>
LEM SEPARATION WEIGHT:	30959	32654	35229

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Table 6a
DERIVATION OF LEM MINIMUM WEIGHT

<u>SUBSYSTEM CHANGE</u>	<u>STAGE</u>	
	<u>ASCENT</u>	<u>DESCENT</u>
Structure	(-80)	(-110)
Revision of L.G. design envelope	-10	-20
Redesign of thermal shielding	-50	-40
Base heat shield redesign		-50
Swage end fittings - trusses	-15	
Laminated windows vs. separate panes	-5	
Stabilization & Control	(-6.0)	
ASA weight reduction	-1.5	
AEA weight reduction	-4.5	
Navigation & Guidance	(-60)	
Star tracker vs. rendezvous radar	-60	
Environmental Control	(-10)	
Redesign of ARS	-10	
Landing Gear		(-110)
Revision of landing velocity envelope		-80
Material substitution (Ti for Al)		-30
Reaction Control	(-48)	
Change O/F from 2.0 to 1.3	?	
Delete pressurization sys. redundancy	-12	
Reduce He bottle safety factor (2/1.5)	-6	
Reduction in maneuvering requirements	-30 *	
Crew Provisions	(-7)	
Redesign of armrests	-7	
Electrical Power	(-33)	
Review of wire harnesses	-20	
Review & revise requirements of lighting control assembly	-8	
Inverter weight reduction	-3	
Elimination of 24 - 30 circuit breakers	-2	

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Table 6a

DERIVATION OF LEM MINIMUM WEIGHT

<u>SUBSYSTEM CHANGE</u>	<u>STAGE</u>	
	<u>ASCENT</u>	<u>DESCENT</u>
Propulsion	(-37)	(-51)
Ascent SHe vs. ambient	-35	
Helium Pressure Decay		-21
Delete propellant quantity gaging		-30
Chem-mill plumbing	-2	
Inert Total:	<u>-281</u>	<u>-271</u>
Effective Weight At Separation: - STAGE	1117	578
	- TOTAL	1695

* Descent Propellant

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Table 6b
DERIVATION OF LEM MAXIMUM WEIGHTS

	<u>SUBSYSTEM CHANGE</u>	<u>STAGE</u>	
		<u>ASCENT</u>	<u>DESCENT</u>
1.	Structure	(175)	(115)
	Revision of critical landing condition.	+30	+25
	Thermal shielding.	+60	+40
	Base heat shield.		+50
	Interior painting.	+20	
	Drogue - docking.	+6	
	Windows - additional thickness (.1 to .16)	+14	
	Sealant	+15	
	Bulkhead and mach. tolerance	+20	
	Chem-mill tolerance	+10	
2.	Stabilization and Control	(7)	
	Reticle - landing aid	+7	
3.	Navigation and Guidance	(6)	
	Landing radar - antenna		
	LEMDE plume effects.	+6	
4.	Crew Provisions	(56)	
	EVTD.	+12	
	APLSS.	+20	
	Tool box and tools.	+10	
	Tracking light.	+7	
	Target.	+4	
	AOT cover (guard).	+3	
5.	Environmental Control	(27)	
	Second water boiler and resizing for 100° maximum battery temperature	+27	
6.	Electrical Power Supply	(40)	(5)
	Wiring	+40	+5
7.	Propulsion	(35)	(406)
	Engine.	+5	+30
	Ambient helium.		+336
	Unuseable propellant.	+30	+40
	Inert Total:	+346	+526
	Effective Weight at Separation:		
	- STAGE:	1453	1122
	- TOTAL:	2575	

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Table 7

LEM SWIP TEAM

CHAIRMAN - T. J. KELLY, LEM PROJECT ENGINEER

ASSISTANT CHAIRMAN - S. SALINA, LEM MASS PROPERTY

P. WIEDENHAEFER, GAEC WEIGHT CONTROL

PARTICIPATING MEMBERS	-	T. ADEE	-	MGR. STRUCTURAL SCIENCES
R. CYPHERS	-	CHIEF, STRUCTURAL SYSTEMS		
R. KLEIN	-	ASS'T CHIEF, THERMODYNAMICS		
N. KOTLARSKY	-	CHIEF, STRUCTURAL ANALYSIS		
E. TOBIN	-	CHIEF, WEIGHT CONTROL		
R. WOOD	-	MGR. DESIGN ENGINEERING		
H. WRIGHT	-	MGR. ELECTRONIC EQUIPMENT ENG.		

SUPPORTED BY ALL LEM ENGINEERING SECTIONS AS REQUIRED.

Table 8
SUPER WEIGHT IMPROVEMENT PROGRAM (SWIP)

- (1) EVALUATE AND ASSIGN AREAS FOR WEIGHT-SAVING DESIGN STUDIES - ALLOCATE MANPOWER.
- (2) REVIEW AND ESTABLISH WEIGHT NEGOTIATION POSITION WITH VENDORS.
- (3) CONDUCT IN-HOUSE DESIGN REVIEWS AND DIRECT IMPLEMENTATION OF RESULTING CHANGES.
- (4) REVIEW AND APPROVE ALL CHANGES SUBMITTED TO CCB OR TO VENDORS. PROPOSE CHANGES TO LEM TOP SPECS WHERE APPROPRIATE.
- (5) INTERFACE WITH NASA COUNTERPARTS.

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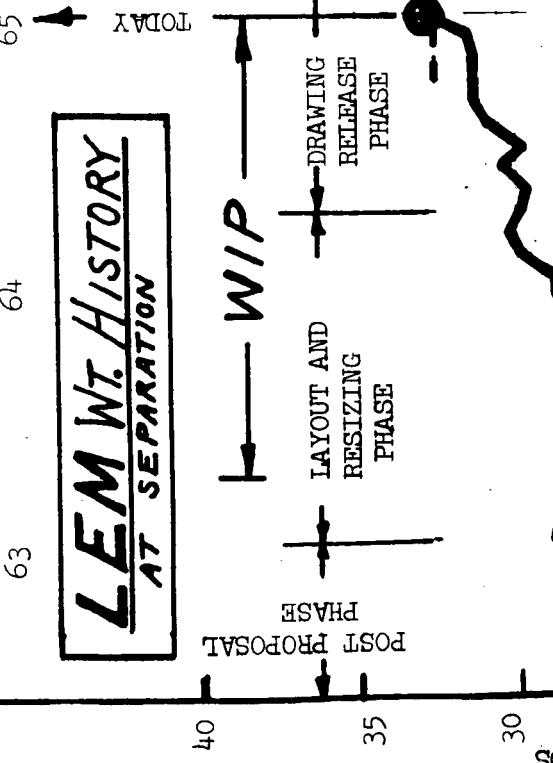
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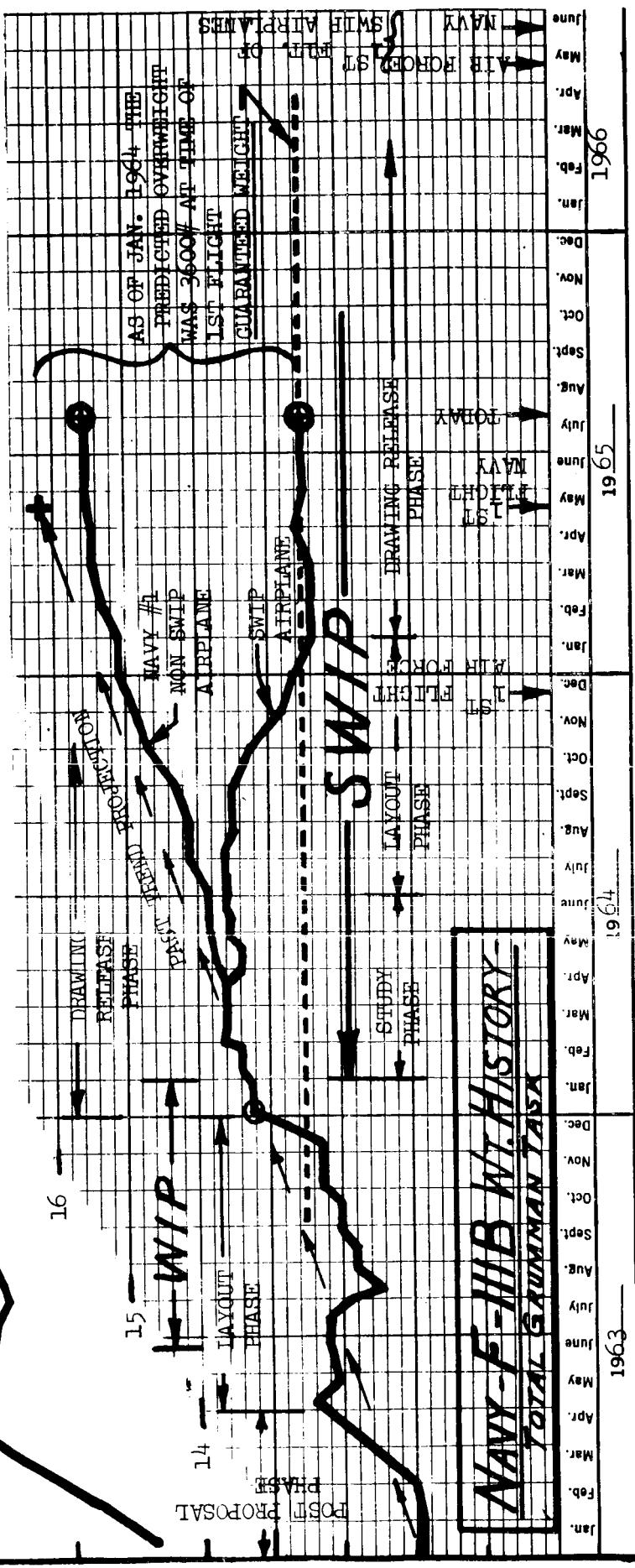
Figure 6

LEM WT. HISTORY AT SEPARATION



WEIGHT - THOUSANDS OF POUNDS

Report LED-490-23 Date 1 August 1965



(Table 9)

F-111 B WEIGHTS

<u>TOTAL F-111B WEIGHT EMPTY</u>	<u>TOTAL GRUMMAN TASK (APPROX. 30% OF TOTAL F-111B WEIGHT EMPTY)</u>
--------------------------------------	--

PROBLEM

Even after the WIP (Weight Improvement Program) phase the predicted overweight as of Jan. 1964 for Navy Airplane at first flight in May 1965 was —————→ +8000 and current overweight at that time was —————→ +2400

+3600
+600

SOLUTION

SWIP (Super Weight Improvement Program)

Initiated Feb. 1964

Study Phase completed in July 1964

SWIP drawing releases started in Jan. 1965

EFFECTS

Total Weight of SWIP items considered	-11500	-2100
Total Weight of SWIP items evaluated to be technically feasible	-8534	-1550
Total Weight of SWIP items approved for incorporation into Design (based on consideration of the total impact to Program)	-4644	-1369
Total resulting SWIP Weight Savings accomplished (based on approximately 80% released drawings and 20% layouts)	-3327	-1057

Table 10DISTRIBUTION OF WEIGHTS AND SWIP SAVINGS

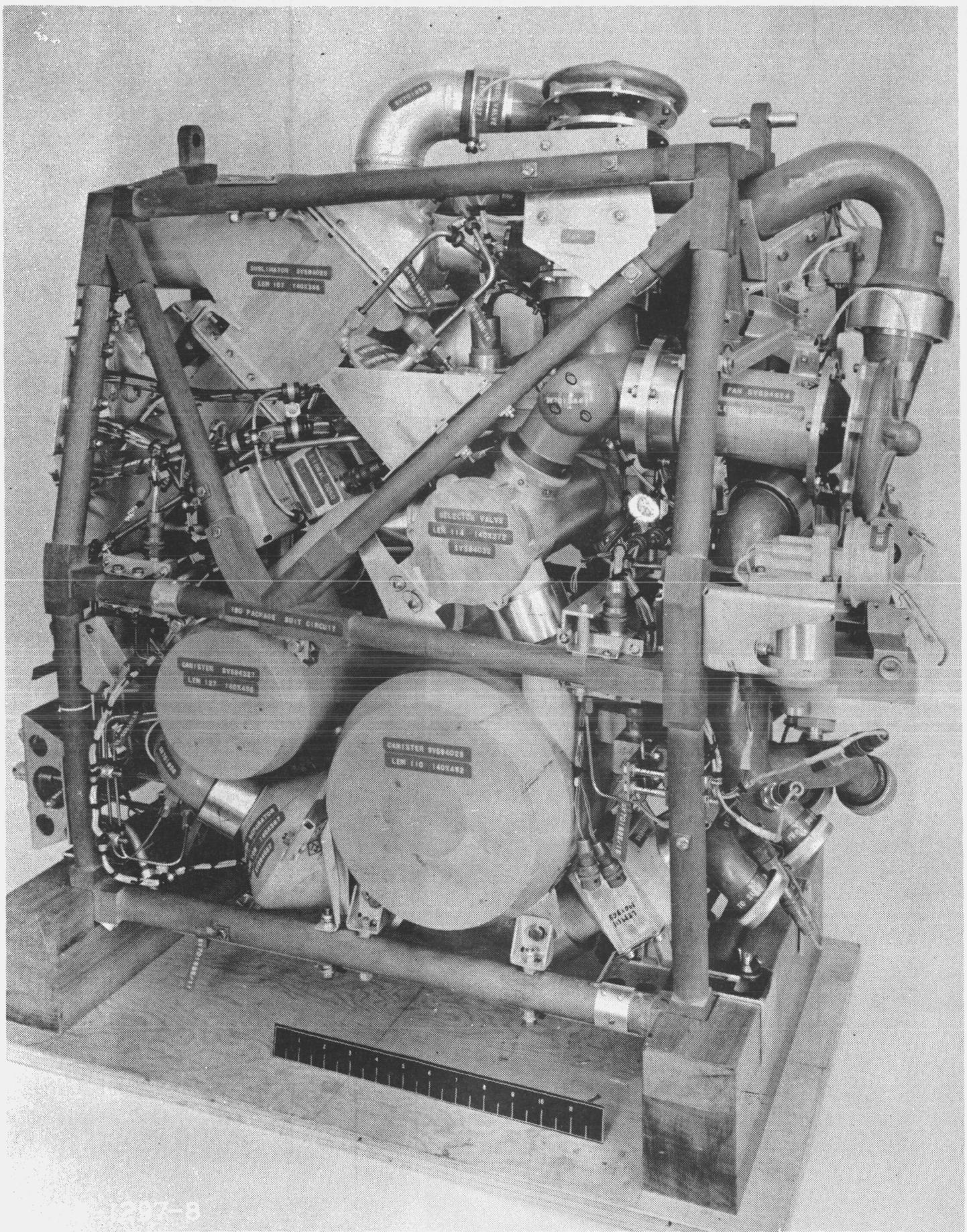
<u>WT. OF ITEMS INVOLVED</u>	<u>F-111B (GRUMMAN TASK)</u>		<u>TOTAL LEM</u>	
	PRESWIP WT.	WT. SAVINGS DUE TO SWIP #/PL %	INERT WT.	AS OF 8-1-65
A. Inhouse Items	10907	-994 -9.1	4846	
B. CFE Items (Vendor)	168	-44 -26.2	3069	
C. GFE Items	2363	-19 -0.8	544	
D. GFE (Transferred from Module includ- ing Crew)		NOT APPLICABLE	615	
E. Expendables (other than ΔV Propellon)		NOT APPLICABLE	1267	
TOTAL	13438	-1057 -7.9	10341	

Table 11

ARS (ATMOSPHERE REVITALIZATION SYSTEM)

CURRENT WEIGHT SUMMARY

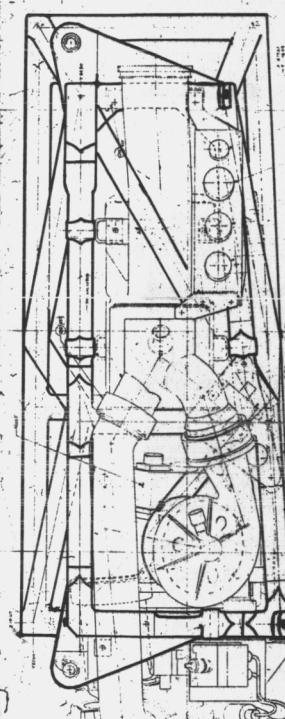
SYSTEM COMPONENTS	=	POUNDS
SUPPORT TRUSS AND FRAME	=	73.6
INSTRUMENTATION (GRUMMAN & HAMILTON STANDARD)	=	11.4
WIRING, CONNECTORS, ETC.	=	3.0
EQUIPMENT SUB TOTAL	=	(88.0)
SUPPORT STRUCTURE SUB TOTAL	=	28.1
BRACKETS, EQUIPMENT SUPPORT FITTINGS, ETC.	=	20.7
TOTAL ARS WEIGHT	=	(48.8)
	=	136.8



R-3

ARS

(Atmosphere Revitalization System)



MAKE 10" BETWEEN
POINTS
A & B

10"

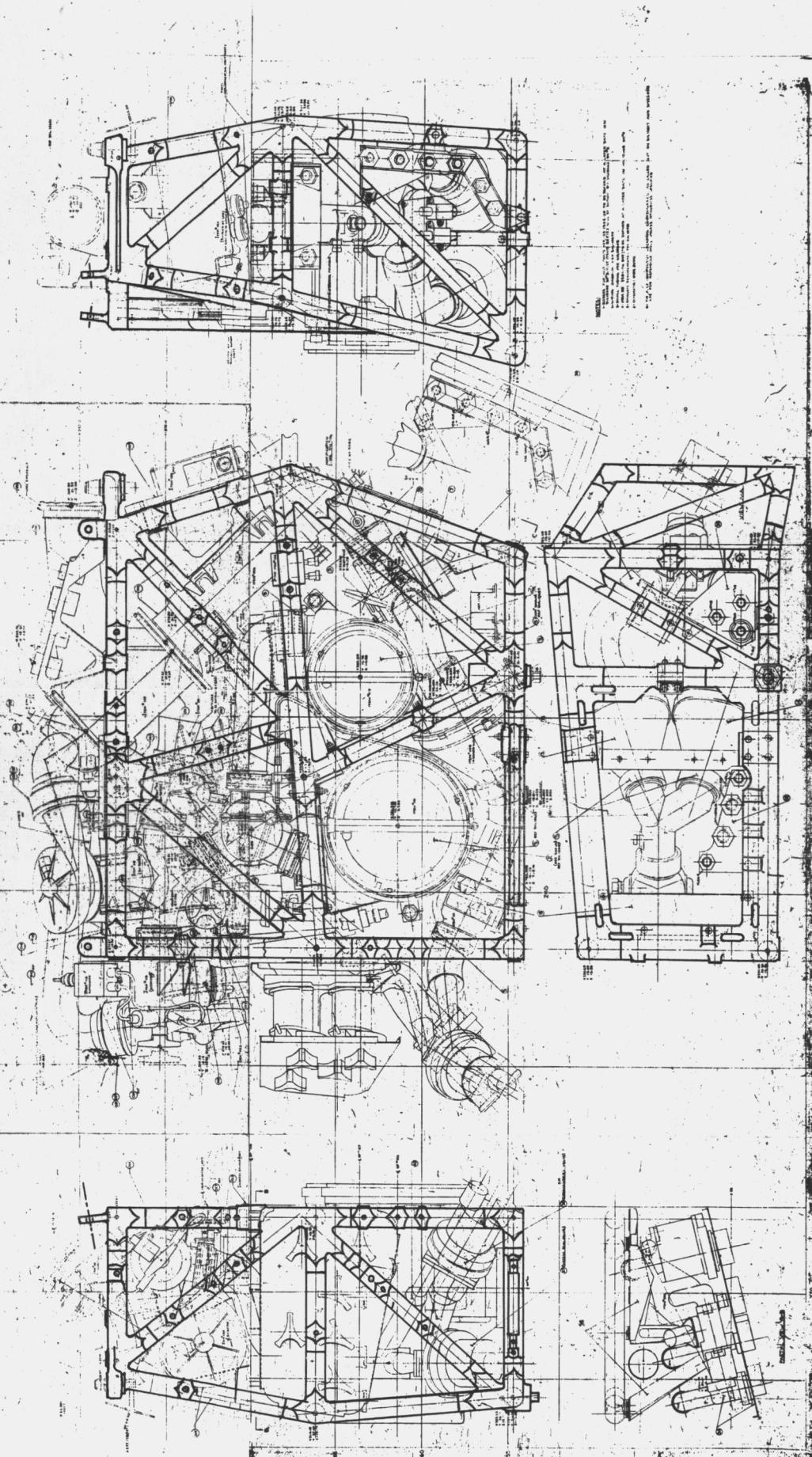


Table 12AGS

(ABORT GUIDANCE SYSTEM)
VENDOR - TRW (STL)

	<u>VENDORS</u> <u>CURRENT</u> <u>WEIGHT</u>	<u>GRUMMAN</u> <u>WT.</u> <u>SAVINGS</u> <u>TO BE INCORP.</u>	<u>ESTABLISHED</u> <u>MAX. NEGOTIABLE</u> <u>SPEC. WEIGHT</u>
AEA (ABORT ELECTRONIC ASSEMBLY)	35.3	-3.6	31.7
ASA (ABORT SENSOR ASSEMBLY)	20.4	-1.5	18.9
DEDA (DATA ENTRY DISPLAY ASSEMBLY)	10.7	-1.7	9.0
	—	—	—
	66.4	-6.8	59.6

LIST OF REFERENCES

1. MSC letter PL2-13-64-571, dated 26 October 1964, "Contract NAS 9-1100, Transmittal of the Apollo Lunar Landing Design Reference Mission Trajectory."
2. MSC letter PP6-13-64-646, dated 20 November 1964, "Contract NAS 9-1100, LEM Weight Report."
3. MSC letter PL2-12-77/13-64-704, dated 14 December 1964, "Contract NAS 9-1100, Resolution of M-5 Mockup Review Chits 1-16- and 1-20."
4. MSC letter BG54 64-406, dated 16 December 1964, "Contract Change Authorization No. 98 Addition of LEM Design Weights to Exhibit A."
5. MSC letter PS5/L630-13-65-178, dated 9 March 1965, "Contract NAS 9-1100, Design Reference Weights for LEM GFE."
6. MSC letter PS5/L204-13-65-460, dated 4 June 1965, "Contract NAS 9-1100, Revised ΔV Budget and LEM Control Weight."
7. MSC letter BG54 65-230, dated 29 June 1965, "Contract NAS 9-1100, Contract Change Authorization No. 113, Portable Life Support System, LEM Stowage."
8. LED-490-22, dated 1 July 1965, "LEM Mass Property Report (U)."
9. LED-490-100 Revision B, Re-issued 15 February 1965, "Allocation of Propellants and ΔV to Meet the ΔV Budget."
10. LAV-500-155, dated 6 July 1965, "Required ΔV For Abort Using the Ascent Engine."
11. LMO-310-58, dated 14 September 1963, "Criteria Used for RCS Tank Resizing."
12. LMO-490-105, Revision A, 29 July 1964, "Preliminary LEM Mass Property History for Control Weight and Current Status."
13. LMO-490-165, dated 10 February 1965, "Ascent and Descent Main Propellant Allocation, Criteria and Assumptions."
14. IMU-340-50025, dated 25 September 1964, Inboard Profile.
15. LDW-280-10050, Revision E, dated 26 May 1965, "Geometry Ascent stage -2 Tank" Drawing.
16. LDW-280-17000, Revision C, dated 17 June 1965, "General Arrangement Descent Stage" Drawing.

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